ELECTROMAGNETIC COMPATIBILITY OF ELECTRIC POWER PLANT

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ABSTRACT

Electromagnetic compatibility is defined as the ability of the device or system to function properly in its electromagnetic environment without entering the intolerable electromagnetic disturbances into that environment. Due to the construction of the electric power system, system components, such as power lines and substations, very often located near other installations that can negatively affect their electrical and magnetic fields, or conductive, inductive and capacitive influence. In the case of approaching some other electrical installations, such as most telecommunication installations, it is necessary to perform the analysis of electromagnetic compatibility and define any possible effects of the relevant infrastructure. The work is considered power station 10(20)/ 0,4 kV provided exclusively for cable (underground) medium voltage network and low voltage outputs, for connecting power line in the vicinity of telecommunication installations and discussed the need for making the project for protection of telecommunication installations.

Keywords: Electromagnetic compatibility; Power plant; Telecommunication installation

INTRODUCTION

In the past most of conventionally used electrical devices (eg, DC motors, resistors ...) were represented by a linear load. Such a character of consumers has resulted in a very small influence between different equipment. Today, most consumer have non-linear character (inverters, fluorescent lamps, computer equipment ...) which produces a certain level of interference and noise. Electric power systems are becoming larger and with increasing installed capacity, which ultimately leads to the increasing the electromagnetic influence. This development leads to the electrical cabling needs of design and installation of more expensive components in the system that are immune to the electromagnetic influence. In order to implement reliable, efficient and economical equipment that is resistant to electromagnetic influences is necessary to conduct the analysis of electromagnetic compatibility and implement a plan for implementing the same in the early phase of the project. Underlying the analysis involves calculation of electric and magnetic fields and low-frequency mutual conductive, inductive and capacitive effect of the installation. Electromagnetic compatibility describes the ability of selected power system to operate without difficulty in enhanced electromagnetic environment and at the same time does not affect the operation of other system components. The main source of each of the electromagnetic effects are the main fields (electric and magnetic) and the current defined in the theory of electrodynamics. At low frequencies the electric and magnetic fields act independently while at higher frequencies significantly only propagating electromagnetic field. The electric field is proportional to the voltage and therefore takes on greater value only in the vicinity of high voltage installations. In most cases, electric fields do not play a significant role since the same, struck any obstacle, significantly weaken or even completely disappear. The magnetic field is proportional to current strength. In many cases, amounts of electricity can take high values, so the increased risk from electromagnetic influences. An example of the electromagnetic effect is flickering monitor in case of a CRT monitor.

TYPES OF ELECTROMAGNETIC INFLUENCES

All mechanisms of the electromagnetic effects are given to describe a very simple model consisting of sources, mechanisms of influence, the media in which the impact occurs and the device over which the impact occurs (Figure 1).

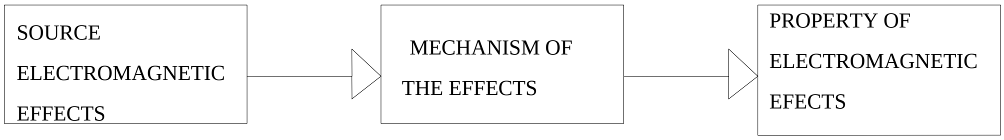


FIGURE 1 Mechanisms of electromagnetic effects

The basic characteristics of different types of electromagnetic effects in power systems are given in the table 1.

TABLE 1 The basic characteristics of different types of electromagnetic effects

Source	**Frequency domen**	**Mechanism of the effects**	**Reach**
Electric field	Low frequency	capacity	Short
Magnetic field	Low frequency	inductance	Short
Electromagnetic field	High frequency	combined	Long

With the three mechanisms described influence there are conducting impact, so, which mainly occurs due to the conductive properties of the earth and the surface. The most common cause of interference due to electromagnetic interference is caused by the inductive influence. Increased use of wireless technologies leads to an increase combined impact. Inductive effect of the electric power facility (Fig.2) on other infrastructure occurs via the mutual inductance between two or more circuits. Equivalent diagram that describes this situation is shown in the figure 2.

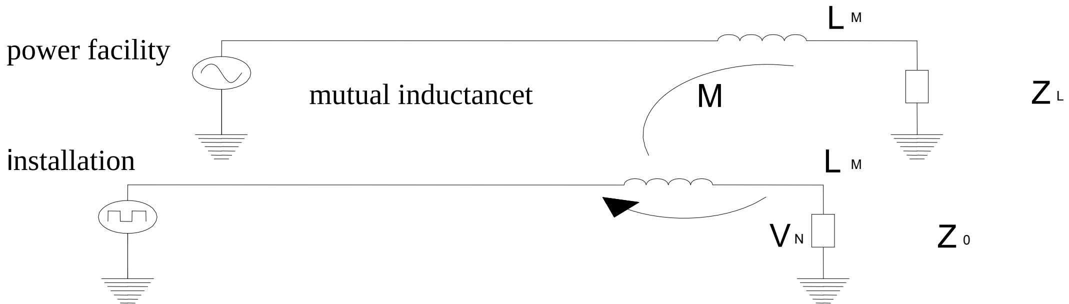


FIGURE 2 Equivalent scheme of the inductive effect of power facilities to other installations

Current that flows through the power circuit creates a magnetic field proportional to current strength. This magnetic flux induces electromotive force (V_N) at a nearby conductor causing a disturbance occurs in a closed current loop circuit other installations. This form of interference is the most common. Size of induced electromotive force V_N is proportional to the current close loop circuit in the electric power facility and the mutual inductance between the respective two rounds. Mutual inductance between the power building and other installations is determined by the geometry of the guide as well as the geometric distance between two lines in the air. Also, the important factor is the environment in which the installations are located. For example, if a compromised installation was performed as a buried cable, a very significant size of the soil resistivity in which the cable is laid.

Conductive the impact of electric power facility (Figure 3) to another installation occurs when two different circuits have a common branch. Equivalent model of the situation is shown in the figure 3.

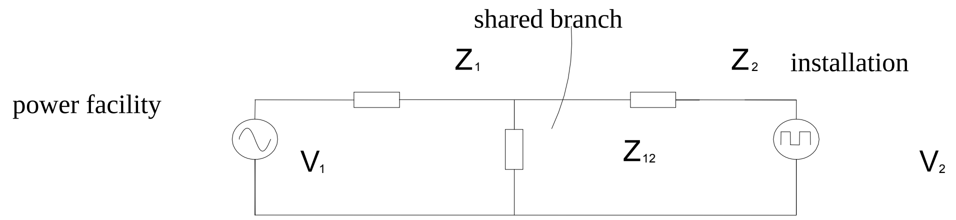


FIGURE 3 Equivalent scheme of conductive impact of power facilities to other installations

In commercial installations, cable, conductive interference between electric and other installations where there is a grounding systems and other networks are not well enough insulated to each other. It follows that this type of coupling in the most dangerous faults in the grounded power network. In such situations, grounding power facilities increase the potential of the country in its vicinity. Therefore, nearby installations can be found at this elevated potential which may result to adverse effects.

Capacitive effect of the electric power facility (Figure 4) to telecommunication (TC) installation occurs through the capacity between two or more circuits. Equivalent diagram that describes this situation is shown in the figure 4.

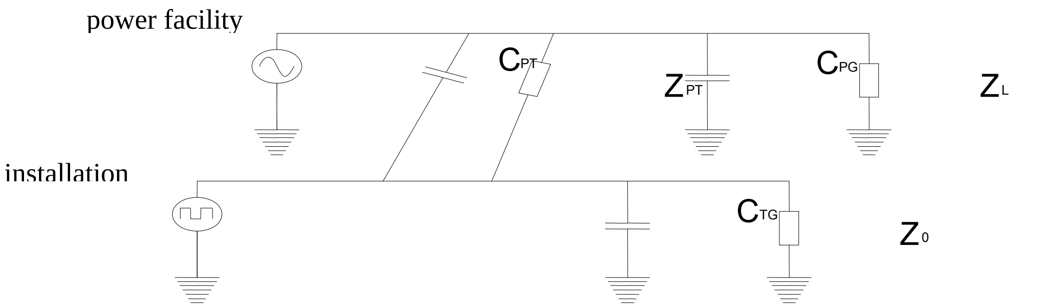


FIGURE 4 Equivalent scheme of capacitive effects of power facilities to other installations

Size of interference caused by capacitive influence is proportional to the size of the capacity between the two circuits (CPT). Capacity CPT determined mutual distance of the installation - is increasing at short distances, and decreases at greater distances. To minimize the impact of power plant installation on TK because of capacitive coupling is necessary to reduce the value of the same capacity. If it is not possible to remove each installation in a sufficiently large distance, and thereby reduce the size of the capacity between the two circuits, it is necessary to take protective measures (eg, screen cable ...).When considering the impact of electric power facility to other infrastructure, have all the previous influences to take into account a combined effect of superposed. Equivalent diagram that describes this situation is shown in slici.5 When the impedance between the two ground marked with Zgg. The overall effect is obtained by adding (superimposing) of individual influence.

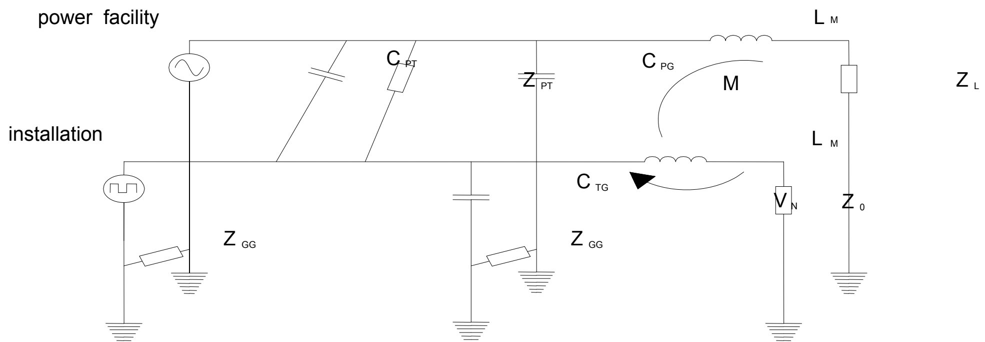


FIGURE 5 Equivalent diagram of the combined impact of power facilities at other installations

REGULATIONS AND CALCULATIONS

JUS standards that reflect the impact of the subject, which are currently accepted as Croatian standards (ISO) have been N.C0.101 HRN, HRN N.C0.102, N.C0.103 HRN, HRN and HRN N.C0.104 N.C0.105 (Official Gazette no. 68/88 yr, RH NN 53/91). (Note that these standards will be replaced with the corresponding European standards). The example describes the application of these standards is a substation with main power cable in the vicinity of telecommunications (TC) installations. A standard that describes how the introduction of TC lines in power plant is ISO N.C0.104. This standard determines the protective measures taken during the introduction of TC lines in power plants with rated voltages above 1000 V. Protective measures provided for in this standard protect TC lines and equipment from hazardous voltages generated within the power plants, transformer stations and distribution plants, and increase the potential ground failure due to power lines and substations. According to these standards, the calculation impact of interference (noise) between the underground power cable and underground TC line is not necessary to check if the power network is performed with isolated neutral or compensated fault current.

Defines the number of sectors depending on the stress cone and the spatial distribution of potential around the ground for grounding, where:

- sector facilities, field fence in the plants on which they applied the measures of adjustment potential. The sector facilities do not appear dangerous step and touch voltages.

- dangerous sector, an area outside the cone voltage installations in which the potential of exceeding 430 V. This sector is determined by measurement or calculation that is verified by measurements for each individual case to determine the point at which the potential of the country below the 430 V high voltage

- sector of high voltage, a sector that includes the sector of machinery and dangerous sector

- harmless sector, a sector where the potential of the country is less than 430 V

- security installation, installation with a higher dielectric strength of telecommunication installations and devices.

It is necessary therefore counting conductive effect that appears to TC infrastructure due to increasing potential soil around grounding, inductive influence of the surrounding lines and capacitive effects on the TC line. Since the distance between power and telecommunication installations great to appear capacitive effect of the relevant infrastructure, it is ignored and has to be calculated and superimposed conductive and inductive effect.Conductive grounding influence of a nearby plant substation calculate the distribution of resources surrounding the land in case of earth fault.Inductive effect is calculated as the induced voltage mutual inductance associated medium voltage cable.Voltage induced with mutual inductance, in general, is

$$E = M\frac{di}{dt} \tag{1}$$

where:

E - induced electromotive force (V), M - mutual inductance (H), $\frac{di}{dt}$ - change current in time (A/s).

Since the current changes in time according to the relation:

$$i(t) = I_m \sin(\omega t) \tag{2}$$

where:

I_m - the maximum value (amplitude) of current, ω - angular frequency current (Hz),

Derivative of the current in time and the taking effective current $I_{ef} = \frac{I_m}{\sqrt{2}}$, is obtained:

$$E = \omega I_{ef} M \tag{3}$$

In the case of approaching or crossing each other power lines and TC lines, longitudinal induced electromotive force expressed in volts, is calculated using the formula:

$E = \omega I_{ef} M l r$

where:

E - induced electromotive force (V), M - mutual inductance (H), ω - angular frequency current (Hz),

I_{ef} - effective current value (kA), l - length approximation (km), r - reduction factor.

Reduction factor r can have values from 0 to 1. The calculation will be done with the value of the reduction factor $r = 1$. This calculation is on the side of safety. Mutual inductance can be estimated from the following diagram (Figure 6) depending on the specific resistance of the earth and the mutual distance transmission lines and metal masses. The actual values of the longitudinal induced electromotive force can be obtained by measuring the actual operation. European standards and directives were made in order that all products made or sold within the European Union are subject to common standards and rules and as such can be used in the markets of member countries without further regulation. In the case of the European EMC Directive 89/336 as amended EU 91/263, 92/31 and 93/97 provides general standards for any product with the goal of electromagnetic compatibility guaranteed with the use restrictions that limit the maximum emission levels of products and its minimal immunity to external electromagnetic impact. When placed on the EU market the manufacturer must select CE product that defines the compliance with EMC and other directives.

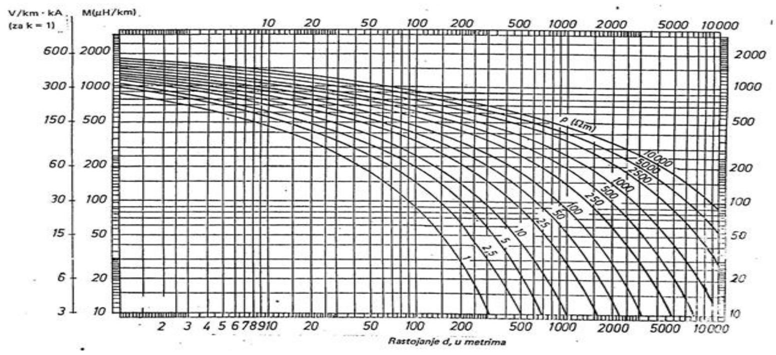


FIGURE 6 Curves for determining the mutual inductance M (µH / km) for f = 50 Hz, depending on the distance d (m) and specific resistance (soil resistivity)

A generic standard that describes the compliance of electrical and electronic devices with the basic restrictions related to human exposure to electromagnetic fields (0 Hz– 300 GHz) is the European standard EN 50392:2004. The same standards are presented method of calculation of electric and magnetic fields in the vicinity of sources such as power plant. Sources of fields of frequency of 50 Hz are power plants. Since most sources it is necessary to point out the high and medium voltage lines and substations. Radiant energy power plant is negligible because the dimensions are the same plants are very small compared to the size of the wavelength power frequency, which is about 6000 km. For this reason, the EM radiation power plants involves action of the electric and magnetic fields. When the distance between the observer and the source of a lot smaller than the wavelength of EM wave, the effects of electric and magnetic fields act independently of the observer. Then we talk about, so-called, near-field. Since the effects of radiation power plants observed at distances up to several hundred meters, the effects of electric and magnetic power frequency fields are discussed separately. The electric field arises as a consequence of the electric voltage. The basic size which also describes the electric field strength $E\ \left(kV/m\right)$. Spreading electrical fields in the environment is different from the spread of the magnetic field in that the electrical field weakens with conductive and grounded obstacles (fences, walls ...), so that very little penetration outside the plant. This stray field that extends beyond the plant depends on the structure of power equipment within it (transformer, bus ...), but rapidly decreases with distance and in the vicinity, but the plant is mostly negligible. The magnetic field arises as a consequence of the flow of electricity. The basic size which also describes the strength of the magnetic reinforced $H\ \left(A/m\right)$. The effects of magnetic fields observed by the size of which is called magnetic flux density $B\ \left(\mu T\right)$. B (µT). Magnetic flux density and magnetic field are related as follows:

$$B = \mu_0 \mu_r H \qquad (4)$$

where:

B - magnetic flux density, H - magnetic field strength,

μ_0 - absolute permeability of vacuum $4\pi 10^{-7}\ (H/m)$, μ_r - relative permeability of media.

The main purpose of transformer substation is transformation of voltage levels within the transformer which are based on a magnetic field. The same field is largely enclosed in the core of the transformer. Part of the magnetic fields are not enclosed in the core and extends beyond it in the form of bulk flows. This especially occurs in case of higher harmonics. Bulk density of magnetic fluxes depends on the size of the current (load), as well as construction (shielding) and the transformer design and construction of the station building. It is particularly important to point out that the transformer stations magnetic flux density decreases rapidly with distance from the station. For example, although immediately against the wall transformer station density magnetic flow can reach high values, but at a distance of several meters, the same size manifold decreases.

Consider substation 10(20)/0,4 kV with main cable which is in the vicinity of telecommunication installations. Transformer station type DTS 10(20)/ 0,4 kV and intended solely for cable (underground) network MV and LV outputs. For the MV cable connector of substation and LV outputs, will be used, where possible, a cable trench. Entry- exit system will join the respective cell type cable XHE 49-A, section 3 x (1x150) mm^2. Transformation voltage transformer shall be 10(20)/ 0,4 kV power rating of 630 (1000) kVA. In case of the substation building is available additional space for the same power transformer. Grounding transformer station is carried out basic and main grounding. Basic electrode was placed in the foundations of the building substation. The main ground electrode consists of two grounding rings like the building station. The first ring was placed 40 cm from the edge of the building substation at a depth of 40 cm. The second ring was placed 100 cm from the edge of the building substation at a depth of 60 cm. Earthing is done FeZn strip 30x4 mm. Specific resistance of the surrounding ground soil resistivity is 100. Network 10(20) kV is isolated and current of earth fault in 20 kV network which is connected substation is 50 A. Slant grounding of substation is shown in figure 7.

Near the station is located TC infrastructure: switching, TC cables and cords SVK. Switching the type: AXE 1992 (95) 2000 ERICSSON connections, together with the power unit type bza 205 54.1 V / 19A, 4 pcs rectifier type BMS 401 013 / 1 and the main distribution frame type BAB 32 631 (4000 pairs), located in a typical brick building, with a basic grounding electrode and grounding strap around the object. The output capacity of the cables - TK 100x4x0 59, 4, 2 pieces - TK 200x4x0 59, 4, 1 st - TK 250x4x0 59, 4, 1 st - TK 300x4x0 59, 4, 3 pcs.

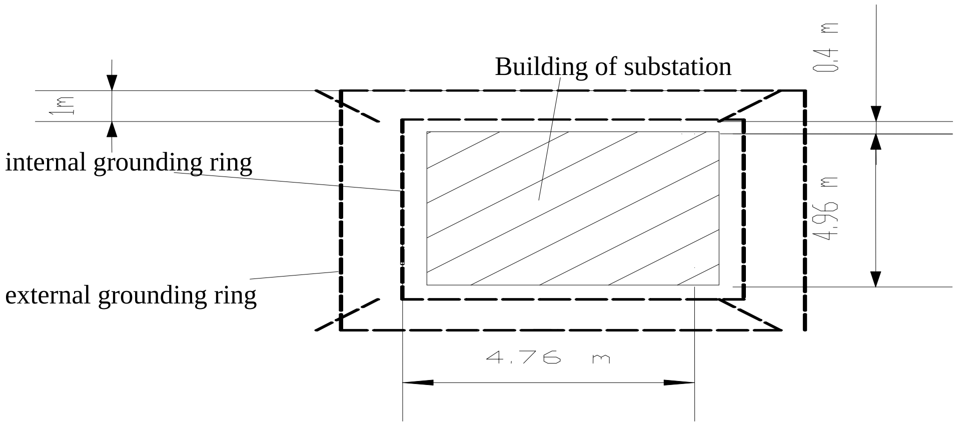


FIGURE 7 Disposition of grounding of substation 10(20)/0,4 kV

Elements of the cable-type TK TK 59 0.4, Figure 8, are as follows:

1. conductor soft annealed copper of 0,4 mm
2. Insulation: foamed polyethylene (PE) with a thin layer of solid PE (foam skin)
3. Stranding elements: Four stars
4. cable core: stranded group (G) or concentrically, filled with filling (M) or unfilled
5. Mantle: laminated, aluminum tape, both sides coated with a copolymer of ethylene formed as a tube flap tightly and permanently glued to polyethylene sheathed black.

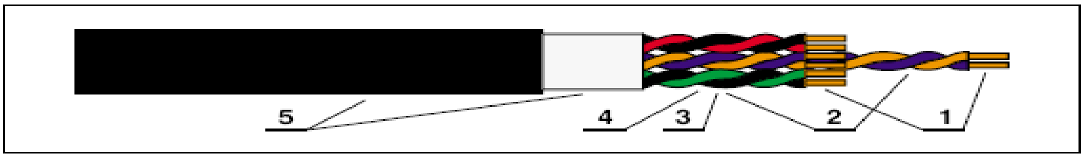
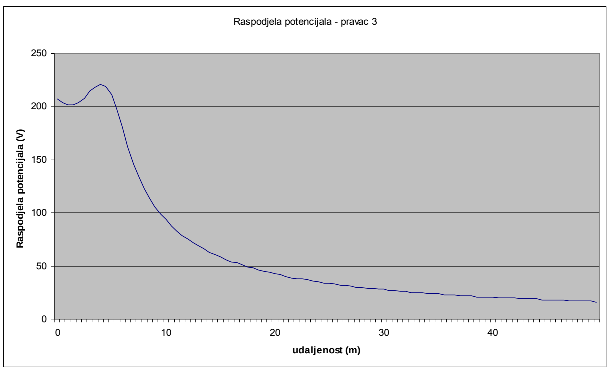


FIGURE 8 Cable type TK 59

These cable apply as a subscriber's local network cables and can be placed in the ground or cable ducts. It is not permitted to use these cables for energy purposes. Basic characteristics of the earthing system are lower soil resistivity and low current fault. The calculation is entered with the value of specific resistance of the soil, which is $\rho_s = 100\ (\Omega m)$. Currents relevant for the calculation of ground voltage, which represents the electricity that goes into the ground, as follows: $I_{ef} = 50A$ .In the near future it is envisaged that the network 10(20) kV is grounded through the device to limit the current (small active resistance). The electricity will be limited to the value of 300 A and it is necessary to calculate the second case when the current is the amount $I_{ef} = 300A$. The increase in installed power of transformation (the installation of additional transformers) will have no impact on the amount of electricity. It was implemented in the program calculation grounding NetGround v. 1.0/2000 with predefined input data. The input data consist of the amount of current that flows into the earth I_{ef} , ρ_s specific resistance of the soil and ground geometry. Distribution of potential (potential funnel) was calculated in three directions with respect to ground. It is clear that the current $I_{ef} = 50A$, due to the failure of the maximum potential of the country in place of the grounding substation is 277,5 V, which is below the limit value of 430 V which defines the dangerous sector of the BS N.C0.104. A place where there is switching, ground potential, or voltage potential risks of the funnel, will amount to less than 270 V. At the same time, the installation of additional transformers will have an impact on increasing the voltage hazards. Supply $I_{ef} = 300A$, due to failure of the maximum potential of the country in place of the grounding substation is more than 1500 V which is above the threshold 430 V defining dangerous sector of the BS N.C0.104. At the distance of 9 m from the edge of the wall of the substation ground potential, or voltage potential risks of the funnel, will amount to 650 V. According to the situation associated with switching cables TK 59 is located at a distance of 9 m from the edge of the wall transformer stations. Further calculations will be carried out with a value of stress due to the potential dangers of the funnel 650 V. Calculate does not take into account the grounding cable in the trenches, which further influence the reduction of ground resistance, and thus the potential of the grounding and the result on the side of safety. It is worth noting that the study presented in this preliminary calculation allocation of resources. Complete and accurate distribution of resources can be obtained by measuring the plant substation. Allocation of resources are given in the diagrams (Figure 9 and 10).



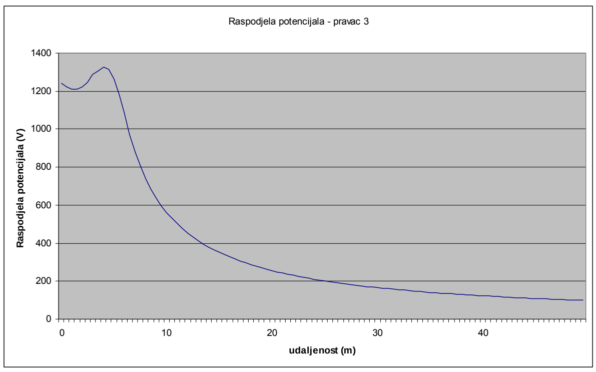


FIGURE 9 Distribution potential $I_{ef} = 50A$

FIGURE 10 Distribution potential $I_{ef} = 300A$

It has been calculated that the total voltage hazard is 278,1 V for $I_{ef} = 50A$, i.e. for medium network with isolated neutral, which is less than 430 V as is permitted subject standards. In this case, it is not necessary to the existing telecommunication installations to take any protective measures in terms of protection from the dangers of increased stress. Is sufficient for mounting the usual protection of TC. It follows that the current situation not require the project for protection of telecommunication installations. The total voltage hazard is 653,6 V, $I_{ef} = 300A$, or if of network earthed via a small active resistance. Since in the foreseeable future planned ground zero point of network active across a small resistance, it can be expected to telecommunication installations high voltage danger in this case. Limit hazardous sectors in this case is about 13 m from the edges of the wall transformer stations. In the case of system operation with a neutral- point grounded through a small resistance to limit current to 300 A, it is necessary to escape TC installed at a distance about 13 m from the substation. It follows that in the case of MV ground network through a small resistance to limit fault current to 300 A in need of a project for protection of telecommunication installations. Also, the calculation shows that the largest contribution to stress the danger comes from the elevated ground potential due to the passage of electricity through the substation grounding. Power cables are on the crossing points with TC installations drawn perpendicular to the telecommunication installations and trained in steel pipe Φ200 which further reduces the impact on the TC infrastructure.

CONCLUSION

Normative regulation solenoid compatibility in BiH should be solved adoption of appropriate legislation in this field in accordance with European Union Directive 89/336/EEC and the harmonized European Standards (EN) that support this directive. The proper way to ensure a high degree of electromagnetic compatibility of the development of appropriate procedures predict situations that may occur in the observed electromagnetic environments. This necessarily requires the study and identification of sources of electromagnetic interference, the transmission path and device sensitivity of disturbed. In electric power plants there are many sources of interference due to the large number of electrical appliances and equipment. However the main sources of interference are switching operations in primary high voltage circuits. Disturbances are transmitted to the sensitive electronic equipment, control systems, signaling, protection, measurement and regulation, as well as process and IT systems, through measurement transformers, metal sheaths of cables, grounding systems, through conductive and radiation. For determining the level of electromagnetic compatibility and evaluation capabilities of the equipment to be resistant to the prescribed level of disturbance, it is necessary to perform the measurement of primary and secondary transient phenomenon during switching operations and measurements in steady state. Program measurements in dynamic conditions defined levels of transient surges that can occur in terms of execution of the disconnectors and circuit breakers at different switching configurations of the installation condition. The purpose of measurement of electromagnetic interference in steady state is establishing a constant high level of electromagnetic interference, and includes the measurement of electromagnetic fields, fluctuations of voltage, pulse voltage and voltage distortion.

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